LCA Case Studies

Life Cycle Assessment of the District Heat Distribution System

Part 1: Pipe Production

Part 1: Pipe Production • Part 2: Network Construction • Part 3: Use Phase and Overall Discussion

Preamble. This series of three papers is based on research performed for the Swedish District Heating Association with the purpose of mapping the environmental life cycle impacts from the different phases involved in district heat distribution. Part 1 concerns the production of the district heating pipes while Part 2 describes the construction of the district heating pipe network. In Part 3, the use phase is evaluated in terms of the long-term thermal performance of different district heating pipes. Part 3 also includes a discussion in which the three evaluated life cycle phases are compared.

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Abstract

Goal, Scope and Background. District heating, the utilization of centrally produced heat for space heating and domestic hot water generation, has the potential to contribute to the eco-efficient use of energy resources in the parts of the world where space heating is needed. In literature, environmental studies on district heating mainly consider the emissions from heat generation; the environmental impact from the distribution system is seldom discussed. This paper presents a life cycle assessment of the production of district heating pipes, based on a cradle-to-gate life cycle inventory commissioned by the Swedish District Heating Association. No external review has been performed but a reference group of district heating experts familiar with the practice was involved in the choice of cases as well as in reviewing parts of the study.

Methods. Manufacturing of district heating pipes at Powerpipe Systems AB, Göteborg, Sweden, was studied. Prefabricated polyurethane insulated district heating pipes were considered, with a steel tube and a protective casing made of high-density polyethylene. Production of pipes during the time period 1999–2000 was investigated. The functional unit used in the study is production of one district heating pipe unit. The studied pipes are: a twin pipe of the dimension DN25 (12m long) and single pipes of the dimensions DN25 (12m), DN100 (12m) and DN500 (16m).

Results and Discussion. A short description of the inventory, some inventory results and a life cycle impact assessment are presented. Characterizations according to GWP, AP, POCP and resource depletion are given as well as two weightings: EcoIndicator99 and Ecoscarcity. If the life cycle is grouped into 'Materials production', 'Transports', 'Manufacturing' and 'Waste management', the 'Materials production' gives rise to a dominating part of the environmental impact.

Recommendation and Perspective. To use materials in the pipes as efficiently as possible is the most important feature in order to reduce the environmental impact from production of district heating pipes. Twin pipes can be a more material efficient solution than single pipes. It is important to make sure that environmental improvements from changes in the pipe production phase are not offset by other effects in the total life cycle of the district heating pipe.

Keywords: District heating; district heat distribution; pipe manufacturing

1 Introduction

District heating, the utilization of centrally produced heat for space heating and domestic hot water generation, has the potential to contribute to the eco-efficient use of energy resources in the parts of the world where space heating is needed. Heat is distributed to the consumers through a network of district heating pipes using water as the transport medium. About 6% of the population in the 15 member countries of the European Union in 1999 covered the domestic heat demand by district heating [1]. The regional variations are large. In Sweden, about 40% of the space heating market is effected by district heating [2]. The Commission of the European Communities has proposed a directive on the promotion of combined heat and power [3] because cogeneration of electricity and heat makes possible a more efficient utilization of the fuel than electricity production alone. District heating is a way to make use of the collected heat.

A district heating system can be divided into four functional parts: heat generation, the distribution system, the sub-stations and the space heating systems [4]. In literature, environmental studies on district heating mainly consider the emissions from heat generation; the environmental impact from the construction of the distribution system is seldom discussed. In this study the distribution system is considered. The life cycle of district heat distribution can be considered to consist of four phases: production of district heating pipes, construction of pipe networks, use of the networks and post-use handling of the networks. Here, the environmental impacts from production of district heating pipes are considered. The full inventory results have been published in Swedish and are available through the commissioner: the Swedish District Heating Association [5]. A summary of the inventory results has been reported in English in a doctoral thesis by Fröling [6]. In this paper, an excerpt of the inventory results is presented together with an impact assessment.

2 System Description and Inventory

In this study, production of district heating pipes is considered. The studied district heating pipes consist of a steel tube, insulated with polyurethane (PUR) foam to avoid large heat losses from the networks. A polyethylene (PE) casing protects the foam layer from damage, water intrusion and thermal ageing due to gas diffusion. The functional unit used in this study is production of one district heating pipe unit. The chosen unit does not directly reflect the function of the district heating pipe (heat distribution) but it was chosen to make it possible to use the results in larger system studies once more parts of the distribution system have been investigated with LCA methodology. The studied district heating pipes are: twin pipe of the dimension DN25 and single pipes of the dimensions DN25, DN100 and DN500. The four cases are described in **Table 1**. Note that the length of one pipe unit differs between the studied pipes. The cases were chosen with the purpose of highlighting different situations. The designs of single and twin district heating pipes are shown in **Fig. 1**. Pipes of different dimensions are not directly interchangeable since they transport different amounts of water. The study is not intended to be a comparison between four different options; any pipe network has to be designed based on the specific characteristics of the network, such as transportation length and heat load. This study covers production of straight district heating pipes; not bends, joints etc. Only cyclopentane-blown foam insulation is considered since this is the standard blowing agent for district heating pipes in Europe at present. So-called Series 2 insulation thickness is considered, which is commercially available and common in Northern Europe. No external review has been performed but a reference group of district heating experts familiar with the practice was involved in the choice of cases as well as in reviewing parts of the study.

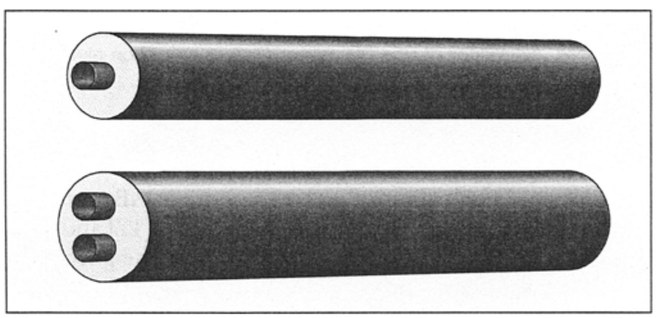

Fig. 1: Single and twin district heating pipes

The activities that make up the investigated product system are shown in **Fig. 2**. Note that only top-level activities are shown. Many of the boxes in the Fig. represent an underlying system of activities.

Manufacturing at Powerpipe Systems AB, Göteborg, Sweden, was studied. Powerpipe Systems AB produces preinsulated district heating pipes in which the cyclopentane-blown foam insulation is moulded between the steel tube and the polyethylene casing. Production of pipes during the time period 1999–2000 was investigated. The results from this study are case specific and depend on the conditions at Powerpipe Systems AB; type and age of equipment, chemicals and materials suppliers etc differ between different district heating pipe manufacturers.

For the top-level activities, shown in Fig. 2, pipe manufacturing data has been gathered from Powerpipe Systems AB (production statistics, environmental report and interviews) and for pipe components and materials, data from suppliers and potential suppliers have been used. For other activities, generic data and average data from literature have been used. The LCAiT (Life Cycle Inventory Tool) software [7] was used to handle the inventory information.

This study covers production of the pipes but not transport to and installation into the district heating network, use of the pipes, or post-use handling. Construction of the factory, machines and auxiliary equipment are not included. The working environment has not been evaluated. Local nuisances such as noise or aesthetic problems concerning the facility or the activities performed at the facility have not been studied.

Consumption of raw materials, spillage, production of waste, consumption of auxiliary materials, chemicals, electricity, oil for heating etc in the factory have been allocated between the pipes based on either the distribution of the materials in the finished products or on the total weight of the district heating pipe.

District heating pipes leaving the factory is a non-elementary output from the studied system. Other non-elementary outputs are: electricity and district heat from waste incineration at the top-level and steel and copper scrap to recy-

Table 1: The district heating pipes studied in the life cycle assessment of production of district heating pipes

Dimension Pipe design	DN25 Twin	DN25 Single	DN100 Single	DN500 Single
Length of pipe unit (m)	12	12	12	16
Steel tube outer diameter (mm)	33.7	33.7	114	508
Steel tube thickness (mm)	2.3	2.3	3.6	6.3
Foam thickness (mm)	–	35	52	89
PE casing, nominal outer diameter (mm)	140	110	225	710
PE casing thickness (mm)	3.2	3.2	3.8	12
Weight of steel tube (kg)	42.7	21.4	118	1250
Weight of PE casing (kg)	15.5	12.2	29.2	388
Weight of PUR foam (kg)	12.5	7.71	26.9	230

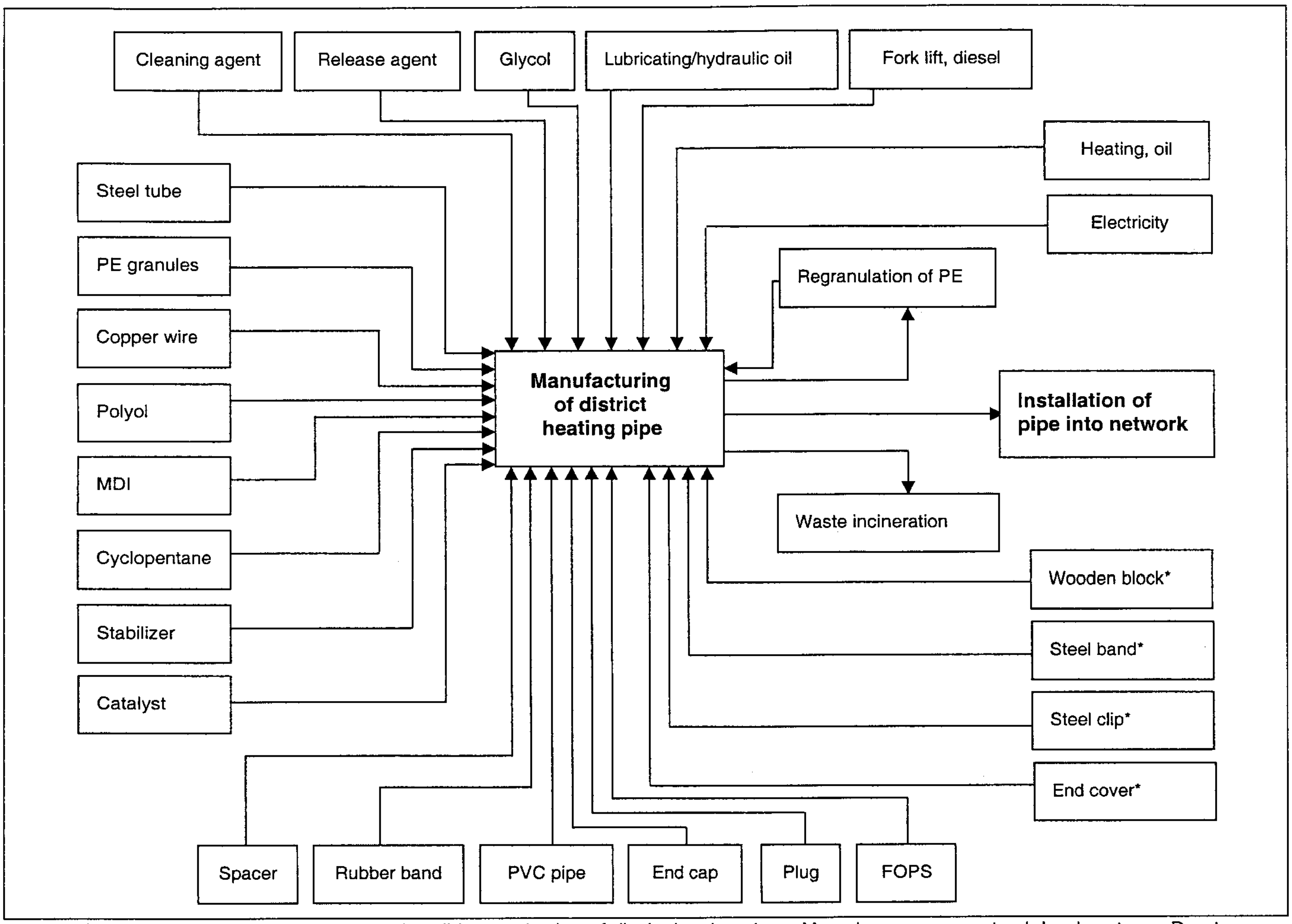

Fig. 2: LCA activities in the product system describing production of district heating pipes. Many boxes represent sub-level systems. Due to space limitations, transports are not shown with boxes; most arrows represent transport activities. 'Installation of pipe into network' represents a non-elementary flow of pipes from the factory. Activities marked * are only relevant for twin pipes

cling. No system expansions were made to include avoided emissions from these flows.

2.1 Raw material production

Average European production data was used for polyol [8], isocyanate (MDI, methylene-diphenyl-4-4'-diisocyanate) [8], polyethylene (HDPE) [9] and steel [10]. The steel is produced from ore. For production of the DN25 and DN100 steel tubes, inventory data for longitudinally welded steel tubes from Wirsbo Stålrör AB, Sweden, was used [11]. For DN500, production of spirally welded steel tubes at Oulainen Works, Finland, was considered [12]. Cyclopentane production is approximated with the average of pentane production at three different facilities in Europe [13]. Energy use is thus slightly underestimated since cyclopentane demands more energy for the distillation than pentane. For land transports of raw materials to the district heating pipe manufacturing facility, the use of a diesel-fuelled [14] heavy truck [15] is assumed; for sea transports, a roll-on/roll-off ferry [15] fuelled by heavy fuel oil [14] is assumed. For polypropylene spacers [13], copper wires [16] and manufacturing aid chemicals, generic emission data is used.

2.2 Pipe manufacturing

For pipe manufacturing at Powerpipe Systems AB, data was gathered from the annual environmental report [17] and from interviews with employees at the plant [18]. The polyethylene casing pipe is produced at the facility from black polyethylene granules. Polypropylene spacers centre the steel tube in the polyethylene casing. More spacers are needed for small dimensions than for large because the stiffness of the polyethylene casing increases with increasing dimension. Rubber bands are used to attach the spacers to the steel tube. In twin pipes, wooden blocks and steel bands maintain the distance between the steel tubes. Alarm wires (two, made of copper) run through all district heating pipes. For twin pipes, an end cover of polyethylene is used to protect the foam surface from sunlight and physical damage. Polyol and production aid chemicals are mixed and injected, together with the isocyanate (MDI), into the cavity between the steel tube and the polyethylene casing through a small hole in the casing. The foaming is effected by formation of carbon dioxide and by evaporation of cyclopentane during polymerisation. About 25 cm of each end of the steel tube is left uncovered to ensure a secure working environment during welding of

the steel joints when the pipes are installed into a network. After foaming, a polyethylene plug is melted into the hole in the casing. To ensure a gas and moisture tight seal, the plugged hole is covered with a foaming hole protection sleeve (FOPS), made of polyethylene. To avoid getting dirt and small animals in the steel tubes during storage and transport, the steel tube ends are covered with polyethylene caps. Diesel fuelled [14] fork lifts are used to transport pipe components and finished pipes within the factory area. Emission data for Swedish conditions around 1990 were used for the fork lifts [19]. Electricity used was assumed to be Swedish average electricity production for 1995 [20].

2.3 Waste management

Deficient polyethylene casings and spillage from the extrusion of casing pipes are regranulated and reused (about 2% of the total consumption). For damaged district heating pipes, the steel tube can often be reused. The casing and the foam are then removed. About 4 tons per year of steel tubes become scrap and are sent for recycling along with 500 kg per year of copper wires. The environmental impacts from steel and copper recycling processes have not been included in the study. Polyurethane spillage from the production and from removal from faulty district heating pipes is sent to waste incineration at a plant in Göteborg, Sweden, along with contaminated polyethylene. Emission data from the general waste incineration at this plant has been used [21].

3 Results and Discussion

The full inventory matrix has been published earlier [5]. Four parameters are shown in **Table 2**, for the four cases. Characterizations and weightings were made to aid in the evaluation of the inventory results. Total results and subresults for groups of activities are presented in **Table 3**. Activities have been added up where no important information is lost by doing so. Activities shown include underlying activities and transports to the factory. Results are reported from characterizations according to global warming potential (GWP, 100 years [22]), acidification potential (AP [22]), photo oxidant creation potential (POCP, high NO_x-background [22]) and resource depletion (statistical reserve life [23]) as well as from two weighting methods: EcoIndicator99 [24] and Ecoscarcity [25]. Some important issues are shown in tables and diagrams and discussed below.

Fig. 3 shows the relative contribution to global warming from four important phases in the life cycle of production of district heating pipes:

- Materials production: Extraction and production of the materials constituting the finished pipe
- Transports: Transports of the materials to the pipe manufacturing plant. Only top-level transports are considered. Other up-stream transports are included in 'Materials production'
- Manufacturing: Activities needed to support pipe manufacturing in the factory
- Waste management: Only top-level waste management is included because this is the level that the pipe manufacturer can have a major influence on

Table 2: Inventory results for the four cases of production of district heating pipes [5]. Unit: kg/pipe unit. Inventory results regarding emissions of fossil carbon dioxide, nitrogen oxides and sulphur oxides to air and emissions of compounds contributing to oxygen demand in water (measured as chemical oxygen demand, COD) are shown. The total results for the system as well as subresults for the activities shown in Figure 1 are shown (in some cases, related activities have been added up)

	DN25, twin				DN25, single				DN100, single				DN500, single			
Inventory parameter	**CO_2**	**NO_x**	**SO_2**	**COD**	**CO_2**	**NO_x**	**SO_2**	**COD**	**CO_2**	**NO_x**	**SO_2**	**COD**	**CO_2**	**NO_x**	**SO_2**	**COD**
Steel tube^T	83	0.11	0.11	0.012	42	0.055	0.054	0.0058	230	0.30	0.30	0.032	2800	4.2	4.0	0.37
Copper wire^T	0.84	0.0067	0.046	0.00015	0.84	0.0067	0.046	0.00015	0.84	0.0067	0.046	0.00015	1.1	0.0089	0.061	0.00020
CASING																
PE granules^T + regranulation^T	15	0.16	0.093	0.0031	12	0.12	0.073	0.0024	28	0.29	0.18	0.0058	370	3.9	2.3	0.078
Plug^T+ FOPS^T	0.019	0.00023	0.00014	3.2E-06	0.019	0.00023	0.00014	3.2E-06	0.019	0.00023	0.00014	3.2E-06	0.019	0.00023	0.00014	3.2E-06
Polyol^T	15	0.069	0.062	0.016	9.2	0.042	0.038	0.0099	32	0.15	0.13	0.035	280	1.3	1.1	0.30
MDI^T	25	0.11	0.11	0.039	16	0.070	0.069	0.024	54	0.24	0.24	0.083	460	2.1	2.0	0.71
OTHER FOAM CONSTITUENTS																
Cyclopentane^T	0.50	0.0028	0.0021	4.9E-05	0.30	0.0017	0.0012	2.9E-05	1.1	0.0060	0.0044	0.00010	9.1	0.051	0.037	0.00089
Stabilizer^T	0.026	7.5E-05	1.2E-05	1.2E-07	0.015	4.3E-05	6.7E-06	6.6E-08	0.055	0.00016	2.5E-05	2.4E-07	0.46	0.0013	0.00021	2.0E-06
Catalyst^T	0.0069	0.00014	8.3E-05	6.8E-08	0.0046	9.2E-05	5.6E-05	4.6E-08	0.016	0.00032	0.00019	1.6E-07	0.14	0.0027	0.0016	1.3E-06
PIPE ACCESSORIES																
Spacer^T + rubber band^T	2.0	0.014	0.014	9.4E-05	1.2	0.0082	0.0080	5.4E-05	3.7	0.025	0.025	0.00017	56	0.38	0.38	0.0027
End cap^T	0.041	0.00022	0.00030	2.7E-06	0.020	0.00011	0.00015	1.4E-06	0.18	0.00094	0.0013	1.2E-05	4.2	0.023	0.032	0.00028
Twin pipe accessories^T	0.44	0.0026	0.0019	0.00026	0	0	0	0	0	0	0	0	0	0	0	0
MANUFACTURING AIDS																
PVC pipe^T	0.10	0.00052	0.00041	3.7E-05	0.10	0.00052	0.00041	3.7E-05	0.10	0.00052	0.00041	3.7E-05	0.21	0.0010	0.00082	7.3E-05
Cleaning agent^T	0.0029	2.2E-05	2.0E-05	3.5E-07	0.0014	1.1E-05	1.0E-05	1.8E-07	0.0060	4.6E-05	4.2E-05	7.4E-07	0.064	0.00049	0.00045	7.8E-06
Release agent^T	0.00016	2.8E-06	1.5E-06	3.7E-09	8.0E-05	1.4E-06	7.2E-07	1.8E-09	0.00034	5.7E-06	3.0E-06	7.7E-09	0.0036	6.1E-05	3.2E-05	8.2E-08
Lubricating/ hydraulic oil	0.0016	1.0E-05	1.0E-05	5.7E-07	0.00079	5.0E-06	5.2E-06	2.8E-07	0.0034	2.1E-05	2.2E-05	1.2E-06	0.036	0.00022	0.00023	1.3E-05
Fork lift + glycol	0.43	0.0080	0.00039	2.0E-05	0.21	0.0040	0.00019	9.8E-06	0.89	0.017	0.00080	4.1E-05	9.5	0.18	0.0085	0.00044
Heating oil	1.9	0.0021	0.0021	8.8E-05	0.95	0.0010	0.0010	4.3E-05	4.0	0.0044	0.0044	0.00018	43	0.047	0.047	0.0019
Electricity	0.76	0.0012	0.00079	2.2E-08	0.37	0.00059	0.00039	1.1E-08	1.6	0.0025	0.0016	4.5E-08	17	0.026	0.017	4.8E-07
Waste incineration	0.63	0.00028	0.00015	0	0.31	0.00014	7.5E-05	0	1.3	0.00059	0.00032	0	14	0.0063	0.0034	0
TOTAL	**150**	**0.49**	**0.44**	**0.070**	**82**	**0.31**	**0.29**	**0.042**	**360**	**1.1**	**0.93**	**0.16**	**4000**	**12**	**10**	**1.5**

^{T} Emissions from transport to the pipe factory are included in the results reported in this table. In Fig. 3, these transports have been separated and added up to show the total impact of top level transports

Table 3: Characterizations and weightings of the inventory results for production of district heating pipes. Activities have been grouped (as indicated in Table 2) to facilitate interpretation of the results

	Steel tube	Copper wire	Casing	Polyol	MDI	Other foam constituents	Pipe accessories	Manuf. aids	Waste incin.	Total
CHARACTERIZATIONS										
GWP [kg CO_2 equivalents]:										
DN25, twin	86	0.87	16	17	29	0.59	2.8	3.3	0.64	**160**
DN25, single	43	0.87	12	10	18	0.35	1.3	1.7	0.31	**88**
DN100, single	240	0.87	30	36	63	1.2	4.3	6.8	1.3	**380**
DN500, single	2900	1.2	390	310	540	11	68	72	14	**4300**
POCP [kg ethene equivalents]:										
DN25, twin	0.040	6.8E-04	0.20	0.0087	0.020	4.0E-04	0.0034	0.0030	4.3E-06	**0.27**
DN25, single	0.020	6.8E-04	0.15	0.0054	0.012	2.4E-04	7.3E-04	0.0015	2.1E-06	**0.20**
DN100, single	0.11	6.8E-04	0.37	0.019	0.042	8.5E-04	0.0027	0.0061	8.9E-06	**0.55**
DN500, single	1.4	9.0E-04	4.9	0.16	0.36	0.0072	0.049	0.064	9.5E-05	**6.9**
AP [kg SO_2 equivalents]:										
DN25, twin	0.20	0.051	0.25	0.12	0.21	0.0049	0.029	0.012	3.7E-04	**0.88**
DN25, single	0.099	0.051	0.20	0.073	0.13	0.0029	0.015	0.0064	1.8E-04	**0.58**
DN100, single	0.55	0.051	0.48	0.26	0.45	0.010	0.046	0.024	7.7E-04	**1.9**
DN500, single	7.3	0.068	6.3	2.2	3.8	0.089	0.72	0.25	0.0081	**21**
Resource depletion [$year^{-1}$]:										
DN25, twin	0.68	0.011	0.56	0.16	0.24	0.015	0.030	0.024	0	**1.70**
DN25, single	0.34	0.011	0.44	0.097	0.15	0.0093	0.012	0.012	0	**1.1**
DN100, single	1.9	0.011	1.1	0.34	0.51	0.033	0.041	0.048	0	**3.9**
DN500, single	22	0.015	14	2.9	4.4	0.28	0.64	0.50	0	**45**
WEIGHTINGS										
EcoIndicator99 [Ecopoints]:										
DN25, twin	3.1	0.37	4.1	1.5	2.4	0.11	0.27	0.25	0.019	**12**
DN25, single	1.6	0.37	3.2	0.92	1.5	0.067	0.13	0.13	0.0095	**7.9**
DN100, single	8.7	0.37	7.6	3.2	5.2	0.24	0.41	0.50	0.040	**26**
DN500, single	110	0.50	100	27	44	2.0	6.4	5.3	0.43	**290**
Ecoscarcity [Ecopoints]:										
DN25, twin	23000	80000	9400	6300	10000	1400	19000	2000	290	**130000**
DN25, single	12000	80000	7400	3900	6300	850	10000	990	140	**110000**
DN100, single	64000	80000	18000	14000	22000	3000	33000	4000	590	**210000**
DN500, single	950000	110000	230000	120000	190000	26000	530000	43000	6300	**1.7E+06**

The results show clearly that the most important environmental impacts are caused by the materials in the pipe before they even leave the gates of the material producers. For all the characterizations and weightings reported here, materials production accounted for between 93 and 99% of the total impact. For the pipe manufacturer this means that the easiest way to decrease the environmental impact from pipe production is probably to make changes in the pipe construction that decrease the materials consumption. Improvements may also be achieved by producing district heating pipes from other materials. Note that the present study is a cradle-to-gate inventory, and suggested changes must be evaluated also regarding effects in later life cycle phases, to avoid negative system effects such as increased heat losses during use.

The contribution to the total impact from the major materials in the pipe is shown in **Table 4**, for the four characterization methods and the two weighting methods. The weight contributions of the different materials present in the pipes are shown in Table 5. Depending on the choice of life cycle impact assessment method, the contribution of the different materials

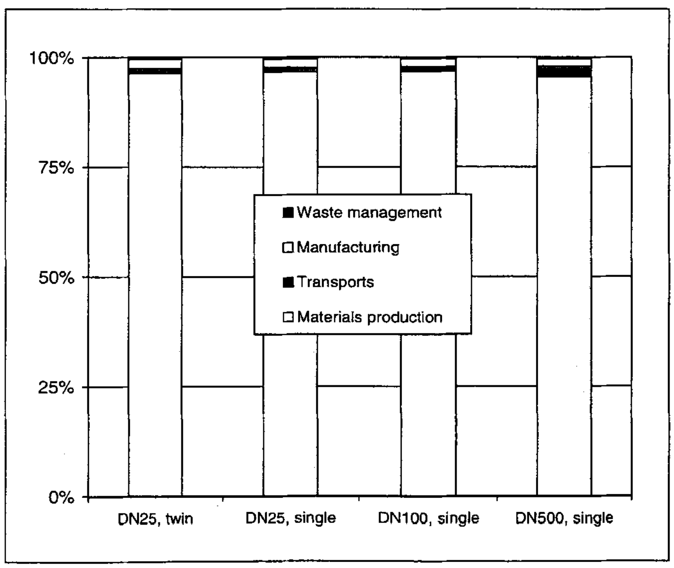

Fig. 3: The relative contribution to global warming (GWP) from the different phases in the life cycle of production of district heating pipes

Table 4: The relative contribution of the major pipe materials to the total environmental impact. In each 'material', all upstream activities directly related to the specific material are included. 'Other' includes all other activities in the studied system

	Pipe dimension	Steel tube	Copper wire	Casing	Foam	Other
		CHARACTERIZATIONS				
GWP	DN25, twin	55%	0.6%	10%	29%	5%
	DN25, single	49%	1.0%	14%	32%	4%
	DN100, single	62%	0.2%	8%	26%	4%
	DN500, single	67%	0.03%	9%	20%	4%
POCP	DN25, twin	15%	0.2%	72%	10%	2%
	DN25, single	10%	0.4%	79%	9%	1%
	DN100, single	20%	0.1%	67%	11%	2%
	DN500, single	20%	0.01%	71%	8%	2%
AP	DN25, twin	23%	6%	29%	37%	5%
	DN25, single	17%	9%	35%	35%	4%
	DN100, single	29%	3%	26%	38%	4%
	DN500, single	35%	0.3%	30%	29%	5%
Resource depletion	DN25, twin	39%	0.7%	33%	23%	4%
	DN25, single	32%	1.0%	41%	23%	3%
	DN100, single	48%	0.3%	27%	22%	3%
	DN500, single	49%	0.03%	31%	16%	3%
		WEIGHTINGS				
EcoIndicator99	DN25, twin	26%	3%	34%	32%	5%
	DN25, single	20%	5%	41%	30%	4%
	DN100, single	33%	1.4%	29%	32%	5%
	DN500, single	36%	0.2%	34%	24%	5%
Ecoscarcity	DN25, twin	17%	60%	7%	12%	4%
	DN25, single	10%	71%	7%	9%	3%
	DN100, single	31%	39%	8%	17%	5%
	DN500, single	55%	6%	14%	18%	7%

Table 5: The contribution of the major materials to the total weight of the district heating pipe

	Steel tube	Copper wire	Casing	Foam
DN25, twin	60%	0.4%	22%	18%
DN25, single	51%	0.8%	29%	19%
DN100, single	68%	0.2%	17%	15%
DN500, single	67%	0.02%	21%	12%

to the total impact will vary. An interesting example is copper wire production. A GWP or a POCP characterization (Table 4) gives a negligible contribution to the total environmental impact from copper wire production while a weighting according to Ecoscarcity (Table 4) relates a major contribution of the impact to the copper wire for some cases, even though the copper wire constitutes less than 1% of the pipe weight (Table 5). This is because Ecoscarcity considers lead (Pb) emissions to air to be relatively important, giving a large contribution from emissions to air during copper production. Another weighting (not presented here) that gives a very large impact from copper production is EPS [26], but because of depletion of copper resources and not emissions to air.

The GWP characterization gives a contribution from each material similar to the weight contribution, with the steel tube as the major contributor. In the POCP characterization, the HDPE casing gives rise to the dominating impact due to hydrocarbon emissions to air. In the AP and the resource depletion characterizations, the impact is spread almost equally between steel tube, casing and foam constituents. The EcoIndicator99 weighting gives a similar result. The copper wire constitutes a larger part of the total impact for the smaller pipes because it makes up a larger part of the total weight in small pipes. The same alarm system is used in all cases: two copper wires running through the pipes. Different dimensions of district heating pipes are generally not comparable since they do not have the exact same function. However, in this study, two of the cases may be compared. One twin pipe can be compared to two single pipes of the same steel tube dimension and length since they may transport the same amount of water. In **Fig. 4**, the impact from production of one twin pipe and two single pipes of the dimension DN25, according to an EcoIndicator99 weighting, are compared. The twin pipe has a lower mate-

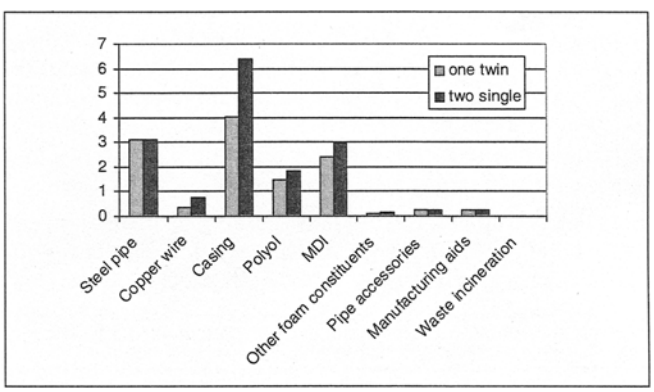

Fig. 4: Comparison of the environmental impact, according to EcoIndicator99, from production of one DN25 twin pipe and two DN25 single pipes. Activities have been grouped together as indicated in Table 2. Unit: Ecopoints

rial consumption than the two single pipes together, giving a lower environmental impact from the twin pipe. A DN25 twin pipe is also expected to be more energy efficient than two DN25 single pipes and a smaller pipe trench is needed for the twin pipe when constructing the network, so that positive effects may be found also in other life cycle phases. For other pipe dimensions, the situation may be different.

It is important always to examine the whole system before starting optimization work on single parts of the system. In this study, we arrive at the conclusion that the efficiency with which the materials in the pipes are used should be increased to decrease the environmental load. But if the foam insulation is made too thin or is completely removed, an increase in energy losses during use of the pipes might quickly off-set any gain in environmental impact related to production of the pipes. Also, if the casing is made too thin or is completely removed, damages to the foam insulation might deteriorate the insulation properties and water intrusion might lead to corrosion of the steel tube.

Other parts of the life cycle of district heating pipes than pipe production will be presented and discussed in the coming parts of this series of papers. A comparison of the different evaluated life cycle phases will be made in Part 3. Preliminary results, reported in Fröling, 2002 [6], indicate that the environmental impact from use of the network is of great importance. Environmental impacts due to heat losses during use of the pipes (from energy generation) may be larger than the total impact from production of the pipes, partly depending on how the heat is generated.

4 Conclusions

Production of the materials in the district heating pipe (mainly steel, polyethylene, polyurethane and copper) are the major contributors (>90%) to the environmental impacts assessed in this study.

For the pipe manufacturer, the easiest way to decrease the environmental impact from pipe production is probably to make changes in the pipe construction that decrease the materials consumption. Improvements may also be achieved by producing district heating pipes from other materials. Suggested changes must be evaluated also regarding effects in later life cycle phases, to avoid negative system effects. If the foam insulation is made too thin or is completely removed, an increase in energy losses during use of the pipes might quickly off-set any gain in environmental impact related to production of the pipes. Also, if the casing is made too thin or is completely removed, damages to the foam insulation might deteriorate the insulation properties and water intrusion might lead to corrosion of the steel tube.

For the DN25 pipes, the use of one twin pipe instead of two single pipes is advantageous for the environment because of material savings.

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